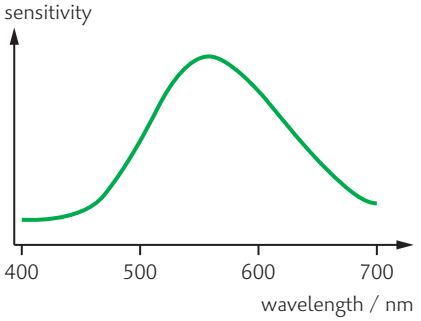
Original Questions

Book 8

Chapter Exercise

Multiple-choice Questions

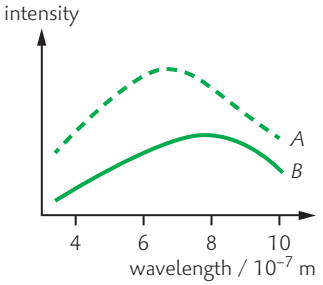
1. The graph below shows how human eyes respond to lights of different colours.



Three different monochromatic light sources *P*, *Q* and *R* emit red, green and blue lights, respectively. The sources produce the same luminous flux with the same input power. Which one has the highest efficacy?

A. *P* B. *Q*
C. *R* D. They have the same efficacy.

2. Initially, an incandescent lamp emits spectrum *A* (dotted line). After some changes, the lamp emits spectrum *B* (solid line).



Which of the following statements is/are correct?

(1) The lamp becomes dimmer.
(2) The pd across the lamp becomes smaller.
(3) The luminous efficacy of the lamp becomes higher.

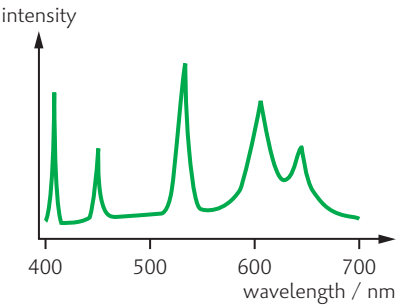
A. (1) only B. (3) only
C. (1) and (2) only D. (2) and (3) only

3. A 100 W incandescent lamp and a 25 W CFL produce the same luminous flux of 1500 lm. Which of the following statements about them is/are correct?

(1) The efficacy of the incandescent lamp is four times that of the CFL.
(2) The spectra emitted by them are identical.
(3) Both give out different amounts of energy in the form of EM waves per unit time.

A. (1) only B. (3) only
C. (1) and (2) only D. (2) and (3) only

4. An FTL emits the following spectrum.



Which of the following is the best explanation for the spectrum produced?

A. The phosphor in the FTL does not produce a continuous spectrum.
B. The mercury vapour inside the FTL does not produce a continuous spectrum.
C. The filament in the FTL does not produce a continuous spectrum.
D. The electrons in the FTL do not produce a continuous spectrum.

5. Gas discharge occurs when a current is formed in a gas due to ionization of the gas. Which of the following statements about the gas discharge in an FTL is/are correct?

(1) At the start, the pd across the tube has to be larger than 220 V.
(2) UV light is produced during this process.
(3) Visible light is produced during this process.

A. (1) only B. (3) only
C. (1) and (2) only D. (2) and (3) only

6. Which of the following statements is/are advantages of using LED lamps over conventional incandescent lamps?

(1) The brightness of LED lamps can be easily controlled by varying the pd across the lamps.

(2) LED lamps can produce a spectrum more similar to that of sunlight.

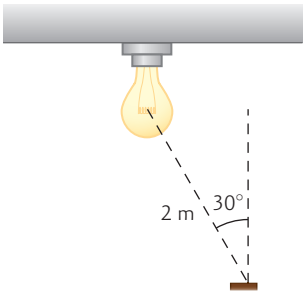
(3) The typical lifetime of LED lamps is much longer than that of incandescent lamps.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

7. A lamp is placed 1 m vertically above the centre of a circular table of radius 1 m. What is the ratio of the illuminance on the brightest surface to that on the dimmest surface?

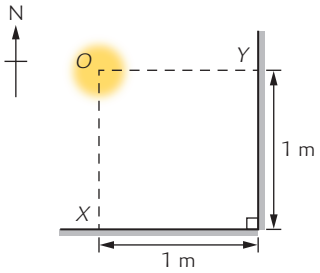
A. $\sqrt{2}:1$
B. $2:1$
C. $\sqrt{8}:1$
D. $4:1$

8. A light source is illuminating a small surface as shown. If the luminous flux produced by the lamp is Φ, what is the illuminance on the surface?



A. $\frac{\Phi}{4\pi}\frac{\cos^3 30°}{2^2}$
B. $\frac{\Phi}{4\pi}\frac{\cos 30°}{2^2}$
C. $\frac{\Phi}{4\pi}\frac{\cos^3 60°}{2^2}$
D. $\frac{\Phi}{4\pi}\frac{\cos 60°}{2^2}$

9. Two small surfaces X and Y are on two walls perpendicular to each other. Initially, a small light source O is equidistant from them such that $OX = OY = 1$ m.



The source is then moved due north by 1 m.

Which of the following statements is/are correct?

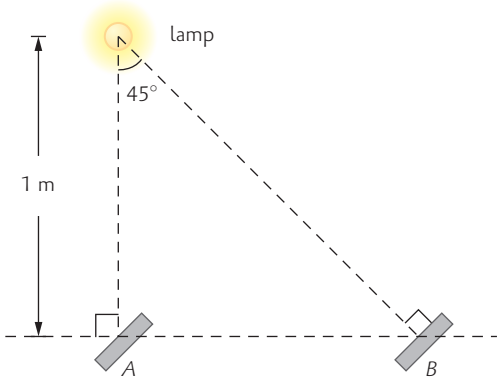
(1) Initially, X and Y have the same illuminance.

(2) The actual illuminance on X and Y depends on the colours of the walls.

(3) After the move, X has a smaller illuminance than Y.

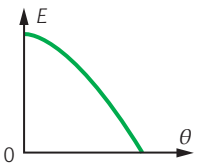
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

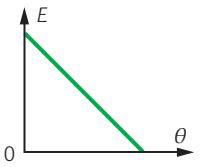
10. Two parallel small surfaces A and B are illuminated by a small lamp as shown. Light is incident normally on B. What is the ratio of illuminance on A to that on B? Given that $\cos 45° = \frac{1}{\sqrt{2}}$.

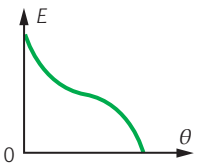


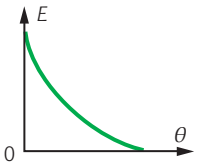
A. $\sqrt{2}:2$
B. $2:\sqrt{2}$
C. $\sqrt{2}:1$
D. $1:\sqrt{2}$

11. A parallel beam of light strikes a small surface at different angles of incidence θ. Which of the following graphs best shows how the illuminance on the surface E varies with θ?

A.


B.


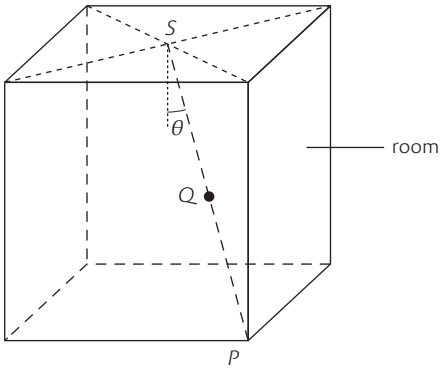
C.


D.


12. **HKDSE 2012** Which of the following lamps has the greatest end-use energy efficiency?

	luminous flux	power rating
A.	750 lm	15 W
B.	900 lm	30 W
C.	750 lm	60 W
D.	600 lm	90 W

13. **HKDSE 2012** Below is a diagram of a room, the illuminance at corner P is E under the illumination of a point light source S as shown. Neglect the reflections from the room surfaces.



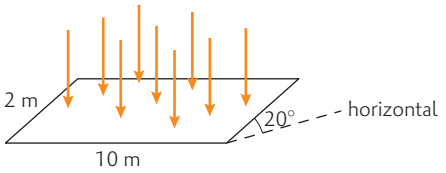
The illuminance at point Q midway between P and S is

A. $\frac{\sqrt{2}E}{\cos\theta}$.
B. $2E\cos\theta$.
C. $4E$.
D. $8E$.

14. **HKDSE 2013** LED usually produces monochromatic light because

A. the difference in energy levels of the p-layer and n-layer in an LED is fixed.
B. its surface is coated with only one type of fluorescent material.
C. the operating temperature of an LED is fixed.
D. current is only allowed to flow through an LED in one direction.

15. **HKDSE 2013** Assume that 1000 W m^{-2} of solar power reaches a certain place vertically on the Earth's surface. What is the power delivered to a solar panel of width 2 m and length 10 m inclined at 20° to the horizontal at that place?



A. 6840 W
B. 7280 W
C. 18 800 W
D. 20 000 W

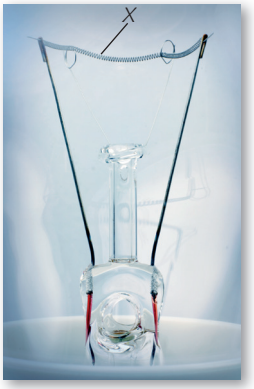
16. **HKDSE 2014** For monochromatic light sources, which of the following pairs appear(s) to be equally bright to our eyes?

(1) 1 lumen of red light and 1 lumen of green light
(2) red light of l watt and green light of 1 watt
(3) red light of 1 watt and 1 lumen of red light

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

Structured Questions

17. The photo is a close-up view of an incandescent lamp.



(a) (i) Name X and suggest a suitable material for making it. (2 marks)

(ii) What is the relation between the thickness of X and the rated power of the lamp? (1 mark)

(b) Consider a new incandescent bulb.

(i) During operation, the two ends of X that connect to the leads are cooler than the middle part. Briefly explain. [Hint: Lead is a good heat conductor.] (1 mark)

(ii) After being used for several hundred hours, the middle part of X becomes thinner. Why? (1 mark)

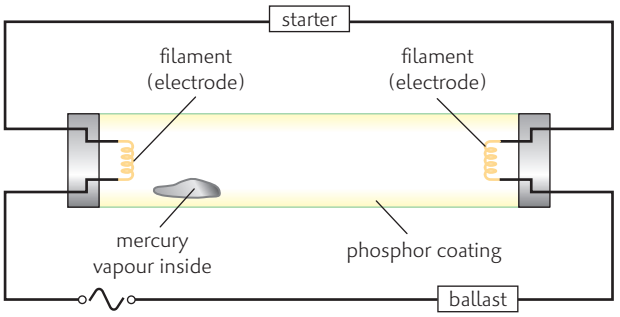
(iii) The thinner part gets thinner at a higher rate. Briefly explain. (2 marks)

(c) An incandescent lamps now works from a 220 V mains. The stable current is 0.3 A.

(i) What is the rated power of the bulb? (1 mark)

(ii) In the first few milliseconds, the rms value of the current keeps changing. Is it increasing or decreasing? Why? (2 marks)

18. The figure shows a schematic diagram of a fluorescent tube lamp (FTL).



(a) (i) A large pd has to be applied across the tube at the beginning. Briefly explain why. (1 mark)

(ii) After a while, the pd across the tube has to be reduced. Why? (1 mark)

(b) (i) Briefly explain how light can be emitted from the lamp. (3 marks)

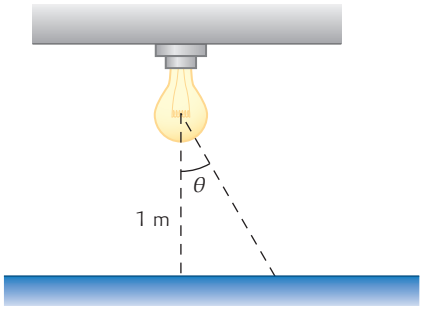
(ii) Why is an FTL more energy efficient than an incandescent lamp? (1 mark)

(c) The lamp shown on the right in the photo is becoming more and more popular as a linear lamp. The lamp makes use of semiconductors to emit light.

(i) Name the light-emitting component in this lamp. Briefly explain how it can emit light. (3 marks)

(ii) Suggest ONE advantage of this lamp over the traditional FTL. (1 mark)

19. Mathew measures the illuminance on a flat surface which is 1 m below a lamp at different angles θ.



He tabulates the results as shown.

angle θ	0°	10°	20°	30°	40°
illuminance E/lx	83	79	69	54	37
X: $\cos^3\theta$					

(a) Mathew plots the illuminance E against a quantity X and obtains a straight line.

(i) What is X? (1 mark)

(ii) Complete the above table and plot the graph of E against X. (4 marks)

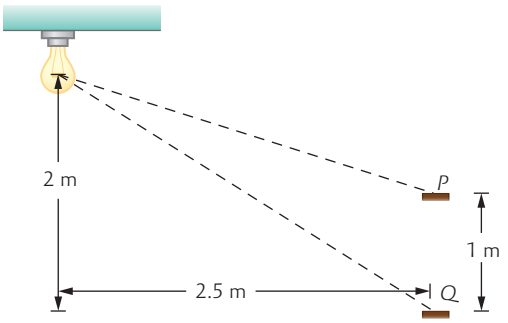
(iii) Estimate the luminous flux produced by the lamp. (2 marks)

(b) The lamp is switched on for 10 hours and consumes a total energy of 2.88 MJ.

(i) Name a suitable device for measuring the energy consumed by the lamp. (1 mark)

(ii) What is the efficacy of the lamp? (2 marks)

20. The figure shows a lamp illuminating two small surfaces P and Q. P is 1 m above Q.



(a) How far are the surfaces from the lamp? (2 marks)

(b) Hence find the illuminance on each of the surfaces in terms of the luminous flux Φ of the lamp. Which surface has a higher illuminance? (4 marks)

(c) (i) If the illuminance of the two surfaces differs by 1.6 lx, estimate the luminous flux Φ of the lamp. (2 marks)

(ii) If the efficacy of the lamp is 20 lm W^{-1}, estimate the electrical power input of the lamp. (2 marks)

Chapter Exercise

Multiple-choice Questions

1. Cooker X boils away a fixed amount of water faster than cooker Y does. Hence we can deduce that X has a higher

(1) output power.
(2) input power.
(3) end-use energy efficiency.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

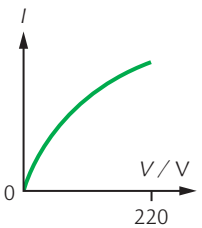
2. Four electric hotplates W, X, Y and Z have rated powers P and end-use energy efficiency η as shown.

	P	η
W	2400 W	48%
X	2200 W	50%
Y	2000 W	60%
Z	1800 W	64%

Which one consumes the least electrical energy to raise the same amount of water by 30 °C?

A. W
B. X
C. Y
D. Z

3. The I–V curve of a heating element is as shown. When it is working at its rated voltage of 220 V, it delivers a heating power of P_1. What is the heating power delivered P_2 when the voltage applied is 110 V?



A. $P_2 = P_1/2$
B. $P_1/4 < P_2 < P_1/2$
C. $P_2 = P_1/4$
D. $P_2 < P_1/4$

4. Which of the following statements about an electric hotplate and an induction cooker is/are correct?

(1) Both make use of the heating effect of a current.
(2) Both require ac current to work properly.
(3) Both require metal cooking utensils to work properly.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

5. Two microwave ovens A and B have the same power input. The time taken for A and B to heat up a specific amount of water from 25 °C to 65 °C is 2 : 3. What is the ratio of their end-use energy efficiency ($\eta_A : \eta_B$)?

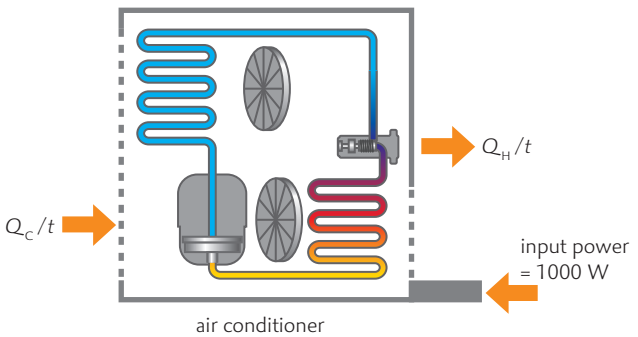
A. 2 : 3
B. 2 : 5
C. 3 : 2
D. 3 : 5

6. During the operation of an air conditioner, in which of the following places does the refrigerant change its state?

(1) Compressor
(2) Evaporator
(3) Expansion valve

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

7. An air conditioner has a COP of 2.5 and its operation is shown by the schematic diagram. Q_H and Q_C represent the amounts of heat disposed to the hot outdoor environment and the heat removed from the cold room, respectively. Suppose the machine works for a time t, what are the values of Q_H/t and Q_C/t?



	Q_H/t	Q_C/t
A.	3500 W	2500 W
B.	2500 W	3500 W
C.	1000 W	2500 W
D.	2500 W	1000 W

8. Which of the following quantities are for measuring the energy efficiency of electrical appliances?

(1) End-use energy efficiency
(2) Luminous efficacy of a lamp
(3) Cooling capacity of an air conditioner

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

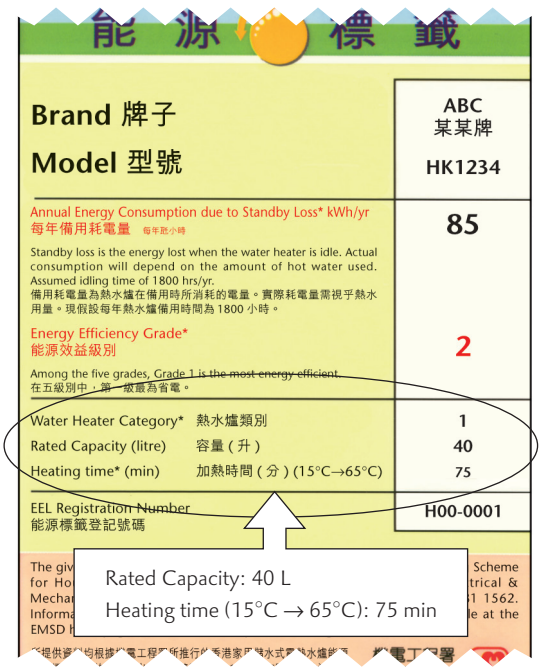
9. **HKDSE 2012** Estimate the time required to cool an insulated room of interior volume 29.0 m^3 from 37 °C to 24 °C by an air conditioner of cooling capacity 2.2 kW.

Given: density of air = 1.2 kg m^{-3}
specific heat capacity of air = 1000 J kg^{-1} K^{-1}

A. 171 s B. 206 s
C. 380 s D. 586 s

10. **HKDSE 2013** Referring to the energy label of a storage type water heater below, estimate the effective output power of the heater when it is filled to maximum capacity with 40 L (1 L = 1000 cm^3) of water at 15 °C.

Given: specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$, density of water = 1000 kg m^{-3}



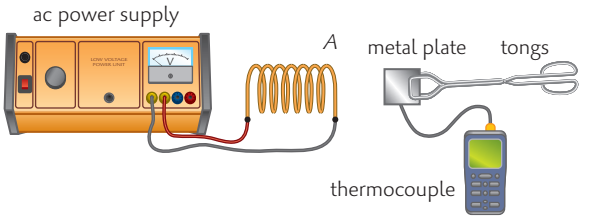
A. 1870 W B. 2430 W
C. 85 000 W D. 112 000 W

11. **HKDSE 2014** The energy labels for air-conditioners show the annual energy consumption (based on 1200 hours of operation per year) and the cooling capacity. Which air-conditioner below is the most energy efficient?

	annual energy consumption / kW h	cooling capacity / kW
A.	672	2.44
B.	684	2.58
C.	696	2.89
D.	750	2.63

Structured Questions

12. Shown below is an experimental set-up for demonstrating the principle of an induction cooker.



(a) Name the component *A*. (1 mark)

(b) Explain how this demonstration works and its relation with the operation of an induction cooker. (3 marks)

(c) Will the demonstration work or not if a dc power supply is used instead? Explain briefly. (2 marks)

(d) Consider a pot of water being heated by a practical induction cooker. The bottom of the pot fits the size suggested by the manufacturer.

(i) Without proper safety devices, the cooking surface can be damaged when all the water is boiled away. Explain briefly. (2 marks)

(ii) Another pot with a bottom of size half of the original is used. Same amount of water is being heated up. Would you expect the heating time be shorter or longer for the same temperature rise? Explain briefly. (2 marks)

13. An electric hotplate has an input power of 1500 W. A student uses it to heat up some water of mass of 1 kg from 15 °C to 65 °C. The end-use energy efficiency in this process is 60%.

(a) (i) How long is the heating process? The specific heat capacity of water is 4200 J kg^{-1} $°C^{-1}$. (2 marks)

(ii) If an induction cooker of the same input power and an end-use efficiency of 75% is used instead, how long will it take? (1 mark)

(b) Explain why an induction cooker is more energy efficient than an electric hotplate. (1 mark)

(c) The student repeats the experiment by heating the same mass of water from 45 °C to 95 °C. He finds that the efficiency calculated is lower than 60%. Give ONE possible reason to explain why. (1 mark)

(d) An electric steamer also uses heating elements to produce heat but a different cooking method is applied. The food is placed in a compartment above a water reservoir. When the steamer is switched on, the water inside the reservoir is heated up.

(i) Briefly describe how heat is transferred to the food by the steam. (1 mark)

(ii) Suggest ONE advantage of using this method to cook over using an electric hotplate. (1 mark)

14. The figure shows a label on a microwave oven.

SPECIFICATION	
MODEL: P803	MODEL NO.: 8538 542 45291
SUPPLY: 220 V ~ 50 Hz	SERIAL NO.: 42 0627 000104
INPUT: 1250 W	FREQUENCY: 2450 MHz

(a) (i) Calculate the wavelength of the microwaves (in cm). The speed of light in a vacuum is 3×10^8 m s^{-1}. (1 mark)

(ii) Explain how food is heated by the microwaves. (2 marks)

(iii) Water molecules absorb microwaves most readily at certain frequencies and vibrate wildly (i.e. at resonance). The lowest one of these frequencies is almost 10 times higher than the operation frequency 2450 MHz. What would happen to the interior of the food if these resonant frequencies were used? (1 mark)

(b) (i) The microwave oven can heat up a cup of water from 25 °C to 65 °C in 1 minute. Suppose the mass of the cup of water is 0.25 kg. Find the end-use energy efficiency of the oven. The specific heat capacity of water is 4200 J kg^{-1} $°C^{-1}$. (3 marks)

(ii) Its end-use energy efficiency is lower than that of a typical induction cooker. Why? (1 mark)

15. An air conditioner with a COP of 2.9 and input electrical power of 1500 W is used in a room of volume 200 m^3.

(a) Find its cooling capacity. (2 marks)

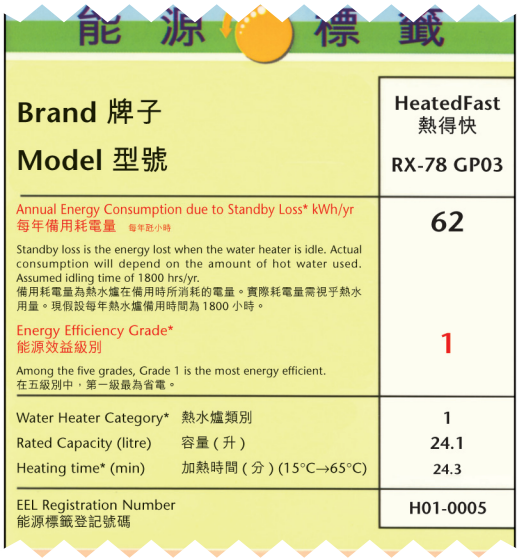
(b) If the air conditioner operates for 10 hours a day, what is the electricity cost in a month (30 days)? Assume that electricity costs $1.1 per kW h. (2 marks)

(c) Estimate the time required for the air conditioner to cool down the air of the room from 30 °C to 25 °C. The density and specific heat capacity of air are 1.2 kg m^{-3} and 1000 J kg^{-1} $°C^{-1}$, respectively. (2 marks)

(d) Suggest ONE other factor that might affect the time it takes to cool the room. Briefly explain how. (2 marks)

(e) Jane claims that replacing the incandescent lamps in the room can reduce the cost for air conditioning. Justify her claim. (2 marks)

16. An electric storage water heater has the energy label as shown.



(a) (i) What is its rated capacity in litres (L)? (1 mark)

(ii) How long does it take to heat some water of a volume same as the capacity in (a)(i) from 15 °C to 65 °C? (1 mark)

(iii) Hence, estimate its power output. The specific heat capacity of water is 4200 J kg^{-1} $°C^{-1}$. Take the density of water to be 1 kg L^{-1}. (2 marks)

(b) The annual energy consumption in the label is not the actual amount of energy consumed by the heater. It is only an estimated standby energy loss based on a certain annual hours of use. Explain what is meant by standby energy loss and estimate the corresponding annual average power loss of the heater in watts. (3 marks)

(c) The heating element is located near the bottom of the storage tank. Briefly explain why. (1 mark)

Chapter Exercise

Multiple-choice Questions

1. A metal plate has an area of 2 m × 2 m and is 5 cm thick. The thermal conductivity of the metal is 60 W m^{-1} K^{-1}. If the two sides of the plate have a constant temperature difference of 10 °C, find the rate of heat flow.

A. 1.5 W
B. 1.5 kW
C. 4.8 kW
D. 48 kW

2. The two surfaces of a plastic layer are maintained at a constant temperature difference, such that heat flows across by conduction. If the width, length and thickness of the layer are all reduced by half, while the temperature difference remains unchanged, how would the rate of heat flow change?

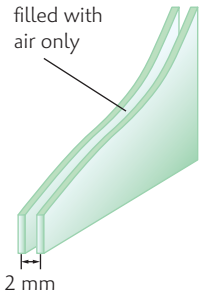
A. Doubles
B. Remains unchanged
C. Reduced by half
D. Reduced by four times

3. Which of the following quantities has the same unit as the rate of heat flow per unit area?

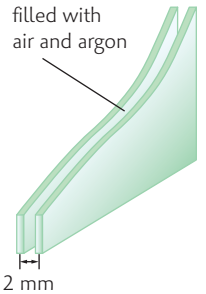
A. U-value
B. OTTV
C. Thermal conductivity
D. Thermal resistance

4. Which of the following double-glazed windows is the most energy efficient? Neglect convection.

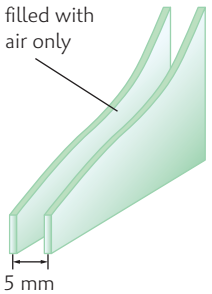
A. filled with air only



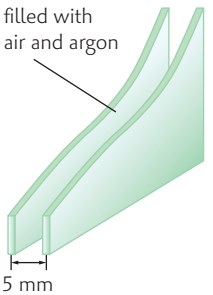
B. filled with air and argon



C. filled with air only



D. filled with air and argon



5. Which of the following statements about an internal combustion engine (ICE) car and a hybrid electric car is/are correct?

(1) An ICE car usually has a smaller engine.
(2) An ICE car usually uses more fuel for the same mileage.
(3) An ICE car usually produces more emissions.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

6. Which of the following is a disadvantage of using a hybrid electric vehicle?

A. Lower mileage range
B. Long recharging time
C. High initial cost
D. Not fuel efficient

7. An electric car has a battery consisting of six 15 V cells. The working voltage of the battery is 90 V. When the car travels at a speed of v, the work done against friction and air resistance is E for every km. Which of the following statements MUST be correct?

(1) The cells are connected in parallel.
(2) The kinetic energy of the car is E.
(3) The power delivered by the car is Ev.

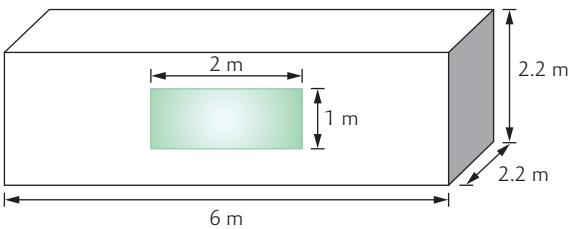
A. (1) only
B. (2) only
C. (3) only
D. None of the above

8. **HKDSE 2012** A container is modified into an office as shown. A window of 1 m × 2 m is installed on the front side of the container. On all the five exposed surfaces, the equivalent temperature difference between the interior and the exterior of the container is 7 °C. (Neglect the inflow of energy due to solar radiation through the window in your calculation.)

Given:

U-value of metallic material of the container = 26.2 W m^{-2} K^{-1}

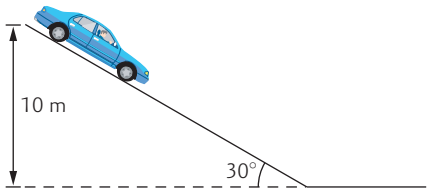
U-value of glass of the window = 1.8 W m^{-2} K^{-1}



Estimate the Overall Thermal Transfer value (OTTV) in W m^{-2} of the container office.

A. 25.2
B. 26.2
C. 176.5
D. 183.4

9. **HKDSE 2013** A car of mass 1000 kg has a regenerative braking system that can convert its kinetic energy into chemical energy which is stored in a battery of that system. How much energy can be stored in the battery after the car has gone downhill at a constant speed by a vertical distance of 10 m? The overall efficiency of the regenerative braking system is 30%. (g = 9.81 m s^{-2})



A. 14.7 kJ
B. 29.4 kJ
C. 49.1 kJ
D. 98.1 kJ

10. **HKDSE 2013** A closed foam box of dimensions 0.5 m × 0.3 m × 0.4 m and thickness 1 cm contains some melting ice. Estimate the rate of heat conducting from the surroundings into the box if the room temperature is 28 °C.

Given: thermal conductivity of the foam is 0.03 W m^{-1} °C^{-1}

A. 39.5 W
B. 79 W
C. 3950 W
D. 7900 W

11. **HKDSE 2013** The Overall Thermal Transfer Value (OTTV) of a building can be reduced by making its glass windows smaller because

(1) glass has a much higher thermal conductivity than concrete.
(2) heat can be transferred by convection if windows are open.
(3) glass allows heat transfer by radiation.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

12. **HKDSE 2014** Which of the following building materials with thicknesses listed below give the best heat insulation?

	material	thermal conductivity / W m^{-1} K^{-1}	thickness / m
A.	concrete	0.50	0.20
B.	wood	0.15	0.05
C.	glass	1.00	0.04
D.	plaster	0.24	0.10

Structured Questions

13. The table below provides the data about a small building.

	walls	roof	windows
rate of heat gain / W	500	2100	3000
total area / m^2	250	145	20

(a) Explain why the heat gain through the windows is so high. (1 mark)

(b) The roof has a heat gain more than four times that of the walls, even though its area is only about 60% of that of the walls. Give two possible reasons. (2 marks)

(c) Calculate the OTTV of the building. (2 marks)

(d) If the heat gain is removed by an air conditioner with a COP of 2.4, estimate the minimum average cost of electricity from air conditioning in a year. Assume there are 365 days in a year and that electricity costs $1.2 per kW h. (2 marks)

14. An electric car of total mass 3200 kg has a battery of capacity 24 kW h (the amount of energy the battery can deliver). When it travels at a speed of 60 km h^{-1}, the power delivered is 15 kW. The efficiency of the motor is 90%.

(a) (i) What is the major energy loss in the motor? (1 mark)

(ii) Estimate the longest distance the car can travel at the speed of 60 km h^{-1}. (3 marks)

(iii) A student claims that the longest distance that the car can travel is actually much shorter than the answer in (a)(ii) due to air resistance and friction. Do you agree? Explain briefly. (2 marks)

(b) To lengthen the travelling time, the electric car is equipped with a regenerative braking system to save energy.

(i) Briefly explain how a regenerative braking system works. (2 marks)

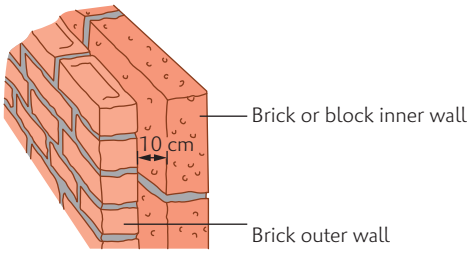
(ii) Suppose the efficiency of the braking system is 40%. How much energy can be saved by the car when it finally comes to a stop if it initially travels at 60 km h^{-1}? (2 marks)

15. **AQA AS-level SC02 Jan 2011** An architect has been asked to draw up plans to convert a garage into an extra room for a house.

She has to design the room using a material with a U-value of 2 W m^{-2} K^{-1} or less for the walls, and a material with a U-value of 1.5 W m^{-2} K^{-1} or less for the ceiling.

(a) Why should the U-value of the ceiling material be less than the U-value of the wall material? (3 marks)

(b) (i) The garage currently has brick walls, 30 cm thick, including a 10 cm air gap.



Suggest ONE change that the architect can make to the design of the walls, to reduce the overall U-value. (1 mark)

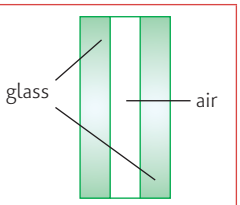
(ii) Explain how this change reduces heat loss. (3 marks)

(c) In a similar room, the wall has an overall U-value of 1.5 W m^{-2} K^{-1}. The wall area is 40 m^2. The room temperature is 20 °C and the outside temperature is 5 °C. At what rate is heat leaving the room through the walls? Use the equation

rate of heat loss = temperature difference × U-value × wall area

(2 marks)

16. (a) **HKDSE Practice Paper** The heat transfer through a window can be reduced by using double-glazed glass. The table below shows some information of two types of windows, both made from the same type of glass.

		
Type	Single layer	Double-glazed
Thickness	0.01 m	0.03 m (0.01 m for each layer)
Thermal transmittance U-value	5.7 W m^{-2} K^{-1}	2.8 W m^{-2} K^{-1}

(i) Suggest TWO reasons why the thermal transmittance of the double-glazed window is smaller than that of the single layer window. (2 marks)

(ii) On a hot sunny afternoon, the temperatures outside and inside a room are 36 °C and 24 °C respectively.

(1) If the double-glazed window is used in the room and the area of the window is 2 m^2, estimate the rate of heat transfer due to conduction through this window. (1 mark)

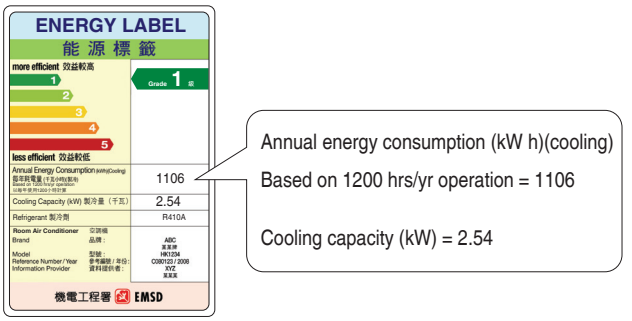
(2) Briefly explain whether the actual rate of heat transfer will be higher or lower than your answer in part (1). (2 marks)

(iii) Other than using double-glazed windows, suggest ONE method to reduce the heat flow through windows. (1 mark)

(b) An air-conditioner is installed in a room to keep the room cool.

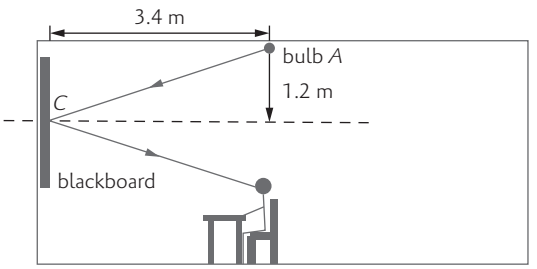
(i) Briefly explain how the refrigerant in an air-conditioner absorbs heat from the room. (2 marks)

(ii) The energy label of the air-conditioner is shown below.



Estimate the amount of heat that can be removed from the room by the air-conditioner in 5 minutes. (2 marks)

17. **HKDSE 2013** The classroom shown in Fig. Q17a has an incandescent light bulb *A* of luminous flux 2000 lm (lumens). You may treat the light bulb as a point light source.

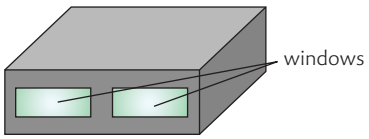


Q17a

(a) Find the illuminance, in lm m^{-2}, by bulb *A* around the blackboard's centre *C*. Neglect any reflection of light. (2 marks)

(b) Bulb *A* is mainly for illuminating the student's desk, however, the light ray reflected back into the student's eyes is undesirable (see the figure). Explain the type of surface that should be used for the blackboard so as to reduce such a problem. (2 marks)

(c) Fig. Q17b shows the appearance of the classroom. The average rate of heat gain of the classroom from outside is 14.5 kW.



Q17b

The classroom is designed to accommodate a maximum of 15 persons at the same time and each person produces on average 100 J of heat per second. There are altogether 6 identical incandescent light bulbs installed to illuminate the classroom and each bulb produces 80 J of heat per second.

(i) Estimate the cooling capacity, in kW, (due to heat produced inside the classroom and heat gain from outside) required for the classroom's air-conditioning system. Assume that there is no other equipment producing heat in the classroom. (2 marks)

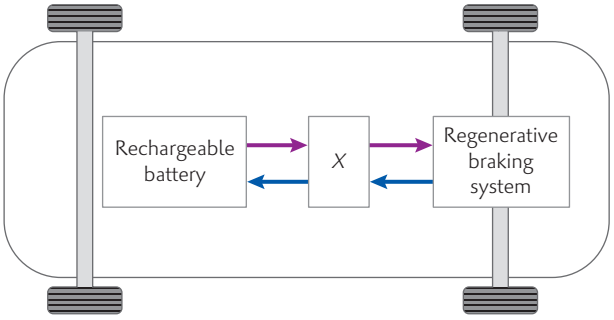
(ii) The power rating of each light bulb is 100 W. The air-conditioning system consumes 0.5 J of electrical energy for removing 1 J of heat from the classroom. Estimate the total monthly cost of electricity for lighting and air-conditioning if the classroom operates 8 hours a day and 20 days a month. Given: cost of electricity = \$1.0 / kW h (3 marks)

(iii) Suggest ONE way of changing either the building structure or the electrical appliance so as to reduce the electricity bill through lower consumption of energy. (1 mark)

18. HKDSE 2014

(a) A completely discharged battery of an electric vehicle is fully charged to store 23 kW h of energy with a terminal voltage of 220 V at an average current of 13 A. Estimate the time in hours required to fully charge the battery. Neglect the internal resistance of the battery. (2 marks)

(b) The figure below shows the schematic diagram of an electric vehicle.



→ denotes the transmission of energy when the vehicle is running
← denotes the transmission of energy during braking

(i) What is the function of component *X* in the figure when the vehicle is accelerating forward? Referring to the figure, describe how the regenerative braking system saves energy during braking. (3 marks)

(ii) Assuming that a fixed percentage of energy is dissipated into heat during braking, would the regenerative braking system be more effective when the electric vehicle is moving at a low speed or a high speed? Explain. (2 marks)

(iii) Why is it necessary for an electric vehicle also be equipped with a mechanical braking system in addition to a regenerative braking system? (1 mark)

(c) Given that typical electric vehicles convert 60% of the electrical energy supplied into the vehicle's mechanical output, consider the following modes of operation of vehicles:

Mode 1	**Conventional petrol vehicles:** 20% of energy stored in petrol is converted to the vehicle's mechanical output.
Mode 2	**Coal-fired power plants + Electric vehicles:** coal-fired power plants are 45% efficient in converting energy stored in coal to electrical energy delivered at socket.
Mode 3	**Nuclear power plants + Electric vehicles:** nuclear power plants are 35% efficient in converting energy stored in fuel rods to electrical energy delivered at socket.

Which mode has the highest **overall energy efficiency**? Does this mode have the minimum **overall emission of air pollutants** among the three modes? Explain your answer. (2 marks)

Chapter Exercise

Multiple-choice Questions

1. Which of the following statements about renewable energy sources is/are correct?

(1) They can be regenerated in a short time.
(2) They do NOT harm the environment.
(3) Nuclear power is one of them.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

2. Most nuclear power plants make use of chain reactions of uranium to produce heat. Which of the following is related to sustaining a steady rate of chain reaction?

(1) Fuel rods
(2) Control rods
(3) Moderator

A. (1) only
B. (2) only
C. (1) and (3) only
D. (1), (2) and (3)

3. A nuclear power plant with a pressurized water reactor (PWR) is working normally. Which of the following statements is/are correct?

(1) Water passing over the reactor core is heated to above 100 °C.
(2) Water passing over the reactor core turns to steam after it absorbs heat and then drives the turbine.
(3) Coolant water that is used to cool the steam contains radioactive substances from the reactor.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

4. In theory, both fission and fusion can be used to generate electricity. However, only fission reactors are employed at present. Which of the following is/are possible reasons?

(1) The fuel for fusion is rare and expensive.
(2) The energy needed to start fusion is far too high.
(3) The fuel is highly radioactive after fusion.

A. (2) only
B. (3) only
C. (1) and (2) only
D. (1) and (3) only

5. The difference in water levels at a hydroelectric power plant is 80 m. Suppose the turbine has an efficiency of 55% and an output power of 1 MW. Estimate how much water passes through the turbine every minute. (g = 9.81 m s^{-2})

A. 2.3×10^3 kg
B. 1.4×10^4 kg
C. 7.6×10^4 kg
D. 1.4×10^5 kg

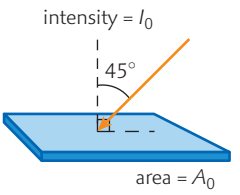
6. The blades of a wind turbine are 12 m long, and are set to rotate when wind blows normally at 10 m s^{-1}. Ten identical turbines are working to generate an electrical power output of 1 MW. Find the efficiency of the turbine. Given: density of air = 1.2 kg m^{-3}

A. 18%
B. 22%
C. 37%
D. 44%

7. Which of the following is an advantage of using wind power over hydroelectric power?

A. The power output by wind power is more stable.
B. The power output by wind power is much larger.
C. Using wind power does NOT affect nearby wildlife.
D. None of the above

8. A solar panel has an area of A_0. Light of intensity I_0 is incident on the panel at an angle of 45° and the power output is P_0. For simplicity, only one light ray is shown.



Assume that the efficiency of the solar cells remains unchanged. Rank the power output when the following measures are taken separately.

(1) Double the area of the panel.
(2) Increase the intensity of the light to $1.5I_0$.
(3) Rotate the panel so that the light is incident along the normal.

A. (1) < (2) < (3)
B. (1) < (2) = (3)
C. (3) = (1) < (2)
D. (3) < (2) < (1)

9. Which of the following pollutants are present in the emissions of a coal-fired power plant?

(1) Carbon dioxide
(2) Sulphur dioxide
(3) Particulates

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

10. **HKDSE 2012** The blades of a wind turbine are 5 m long, which are set to rotate when wind blows normally at 12 m s^{-1}. The overall efficiency of the wind turbine is 25%. Estimate the number of wind turbines required to generate an electrical power output of 1 MW. Given: density of air = 1.2 kg m^{-3}

A. 12
B. 49
C. 122
D. 196

11. **HKDSE 2012** What would happen if the moderator of a nuclear fission reactor fails to function?

A. The chain reaction might stop eventually.
B. Neutrons CANNOT be absorbed by the moderator.
C. Heat CANNOT be transferred to the steam generator.
D. The fuel rods might melt down.

12. **HKDSE 2013** A wind turbine is used to drive a pump which pumps water up to a storage reservoir. The blade-length of the wind turbine is 10 m while the average wind speed is 5 m s^{-1}. How much water can be pumped up to the reservoir in 8 hours if the overall efficiency of the system is 20%? Assume that the average gain in gravitational potential energy by water is 981 J kg^{-1}. Given: density of air = 1.23 kg m^{-3}

A. 39.4 kg
B. 2.84×10^4 kg
C. 1.15×10^5 kg
D. 1.42×10^5 kg

13. **HKDSE 2013** When four hydrogen nuclei, each of mass 1.007 825 u, are fused together, one nucleus of element *Q* of mass 4.002 603 u is formed. Which of the following statements is/are correct?

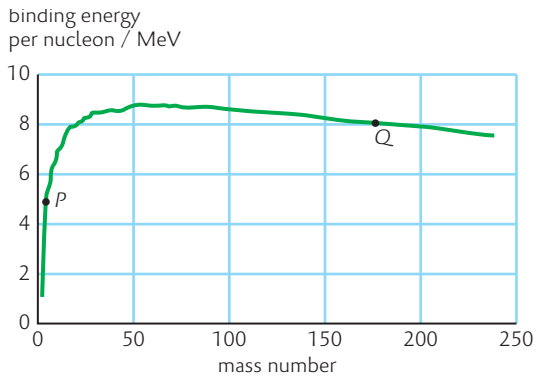
(1) Hydrogen nuclei need to have extremely high kinetic energy to start the fusion process.
(2) Energy released in the process is about 26.7 MeV.
(3) Element *Q* is radioactive.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

14. **HKDSE 2014** A wind turbine generator experiences wind blowing normal to it with variable speed such that the wind speed is 1 m s^{-1} for the first two minutes and 2 m s^{-1} for the third minute. What is its average power output, in W, for this period of 3 minutes if the overall efficiency of the generator is 30% and the length of each blade is 20 m? Given: ρ = density of air in kg m^{-3}.

A. $180\pi\rho$
B. $200\pi\rho$
C. $600\pi\rho$
D. $667\pi\rho$

15. **HKDSE 2014** The curve below shows the binding energy per nucleon of nuclides of different mass numbers.



Which of the following statements is/are correct?

(1) Nuclei of *P* can release energy by nuclear fusion.
(2) Nuclei of *Q* can release energy by nuclear fission.
(3) Nuclei of *P* are more stable than nuclei of *Q*.

A. (2) only
B. (1) and (2) only
C. (1) and (3) only
D. (1), (2) and (3)

Structured Questions

16. Fig. Q16 (page bottom) is a schematic diagram of a nuclear power plant.

(a) Briefly describe how heat is generated by the fuel rods. (2 marks)

(b) What is the purpose of

(i) the control rods? (1 mark)

(ii) the moderator? (1 mark)

(c) Suggest ONE reason why the steam used to drive the turbine is NOT directly produced by passing water through the reactor core. (1 mark)

One day, scientists may be able to use the fusion of deuterium ($^2_1$H) and tritium ($^3_1$H) to produce a sustainable source of energy. The reaction is as follows:

$$^2_1\text{H} + {}^3_1\text{H} \longrightarrow {}^4_2\text{He} + {}^1_0\text{n}$$

Given: atomic mass of $^2_1$H = 2.014 102 u
atomic mass of $^3_1$H = 3.016 049 u
atomic mass of $^4_2$He = 4.002 602 u
mass of a neutron = 1.008 665 u
1 u is equivalent to 1.492×10^{-10} J

(d) Find the energy released for the formation of one helium atom in the above reaction. Express your answer in joules. (2 marks)

(e) A future reactor makes use of the above reaction to generate electricity and has an output power of 1200 MW.

(i) Suggest ONE advantage of using a fusion reactor over a fission reactor. (1 mark)

(ii) Estimate the number of reactions that take place every second. (2 marks)

17. A wind turbine of blade length ℓ is subject to wind of speed v in the normal direction.

(a) The maximum wind power captured by the wind turbine is

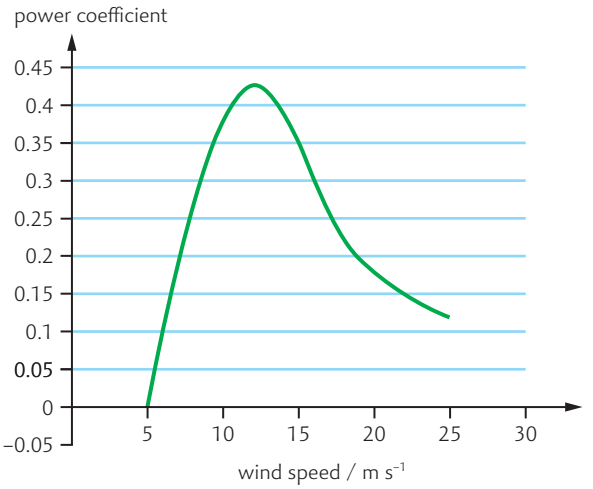
$$P_{max} = \frac{1}{2}\rho\pi\ell^2 v^3.$$

However, no wind turbine can achieve this power. Suggest TWO reasons. (2 marks)

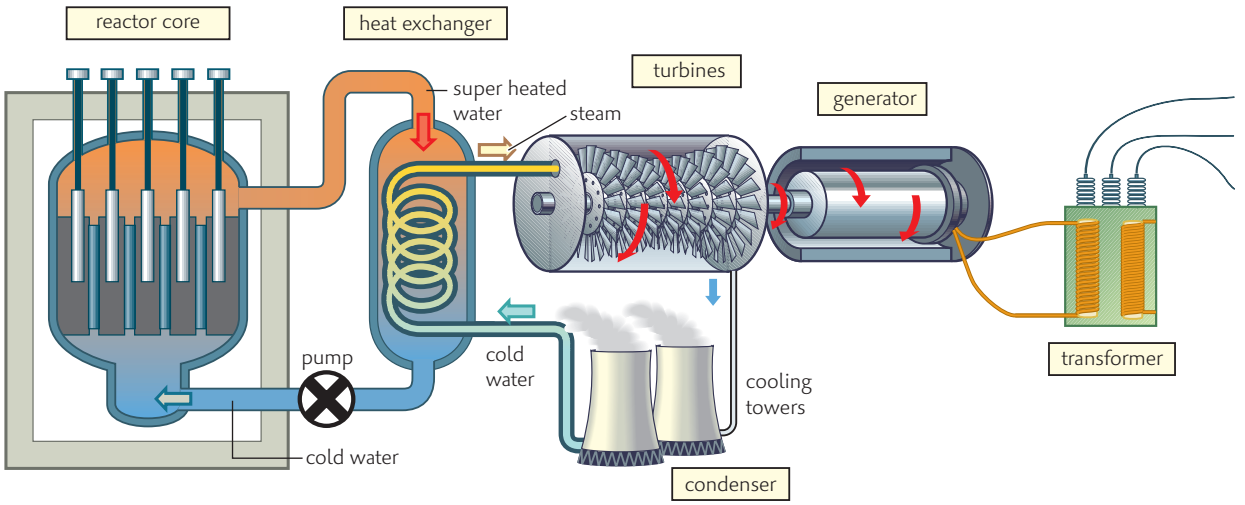
(b) For realistic wind turbines, the actual power P captured by the turbine is given by

$$P = \alpha P_{max}$$

where α is called the power coefficient. It depends on the design of the turbine and the wind speed. The figure below shows how the value of α changes with wind speed.



Suppose ℓ = 20 m and ρ = 1.3 kg m^{-3}, estimate the actual power captured by the wind turbine when v = 10 m s^{-1}. (2 marks)



Q16

(c) State ONE advantage and ONE disadvantage of using wind power to generate electricity compared with a conventional coal-burning power station. (2 marks)

(d) A wind power station usually has backup from a conventional power station. Why? (1 mark)

18. A hydroelectric power plant is capable to generate electricity at 2400 MW. The upper and the lower reservoirs have a difference of 535 m in height and the overall efficiency of the station is about 76%. Take $g = 9.81\ m\ s^{-2}$.

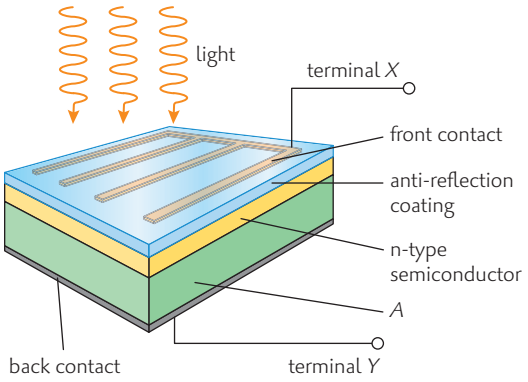
(a) The overall efficiency cannot reach 100%. Suggest TWO possible reasons. (2 marks)

(b) How much water flows through the turbine every second? (2 marks)

(c) Using hydroelectric power to generate electricity can cause various environmental impacts, despite no emissions being produced. Suggest TWO possible impacts. (2 marks)

(d) Give TWO advantages of using hydroelectric power to generate electricity as compared with wind power. (2 marks)

19. The figure shows the schematic diagram of a solar cell.



(a) (i) Name part *A*. (1 mark)

(ii) The n-type semiconductor is very thin. Suggest ONE reason. (1 mark)

(b) The terminals *X* and *Y* are now connected to a load of 20 Ω. A current of 0.15 A flows through the load.

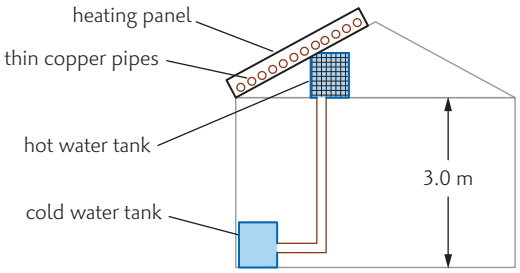
(i) Which terminal, *X* or *Y*, acts as a positive terminal of the cell? (1 mark)

(ii) Briefly describe how a current is produced. (4 marks)

(iii) The area of the cell is 25 cm^2. Suppose sunlight of intensity 800 $W\ m^{-2}$ falls on the cell perpendicularly. Find the efficiency of the cell. (2 marks)

(c) It is difficult to use solar power to generate electricity on a large scale in Hong Kong. Suggest ONE possible reason. (1 mark)

20. **AQA Applied Science SC02 Jun 2012** An engineer is considering fitting solar heating panels to the roof of her house. These will absorb radiation from the Sun and heat water for use in her house. The figure shows a side view of the house, one heating panel and water tanks.



The engineer has decided to use many thin copper pipes in each panel, rather than one thick one. She asked for the outside of the pipes to be painted.

(a) What colour should the outside of the pipes be painted? (1 mark)

(b) Why should the engineer use copper pipes rather than plastic ones? (2 marks)

(c) The engineer initially finds that all the hot water stays in the panel, and the cold water stays in the lower tank. Explain why this happens. (2 marks)

(d) The engineer decides to fit a small pump to circulate the water. The pump is designed to lift 20 litres of water (20 kg) by 3 metres, in a fixed time period. Assume that $g = 10\ m\ s^{-2}$. How much gravitational potential energy is gained when 20 kg is lifted by 3 m? State the correct unit in your answer. (3 marks)

(e) The engineer wants to power the pump from a small solar cell placed next to the panel. A friend suggests that she should use the mains electricity supply to power the pump. Suggest TWO advantages of using a solar cell, rather than the mains, to power the pump. (2 marks)

(f) The engineer wants to compare her panel (the Aqa-panel) with a rival company's panel (the Heatalot). She plans to install an Aqa-panel on every second house in the street, and a Heatalot panel on the others. She will then measure the heat delivered to the hot water system of each house. Suggest TWO precautions she should take to make her comparison of the heating systems a fair test. (2 marks)

(g) The company accountant suggests that the engineer should cut the costs of the comparison by using one Aqa-panel and one Heatalot panel. The output from each of the panels, for one day, could then be compared. The engineer intends to make this a reliable scientific comparison. How could she explain to the accountant why she needs to use several panels? (2 marks)

21. **OCR Physics A Jun 2012** The nuclear reaction is represented by the equation

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{94}_{39}\mathrm{Y} + {}^{139}_{53}\mathrm{I} + 3{}^{1}_{0}\mathrm{n}$$

takes place in the core of a nuclear reactor at a power station.

(a) Describe how this reaction can lead to a chain reaction. (1 mark)

(b) Explain the role of fuel rods, control rods and a moderator in a nuclear reactor. In your answer you should make clear how chain reactions are controlled in the reactor. (5 marks)

(c) In the nuclear reactor of a power station, each fission reaction of uranium produces 3.2×10^{-11} J of energy. The electrical power output of the power station is 3.0 GW. The efficiency of the system that transforms nuclear energy into electrical energy is 22%. Calculate

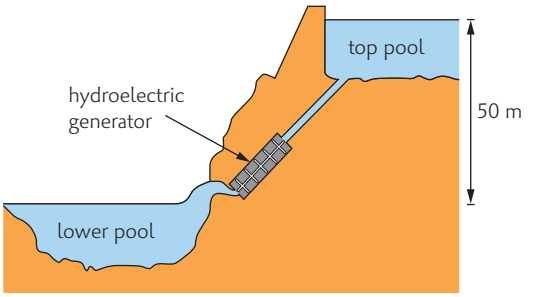
(i) the total power output of the reactor core. (1 mark)

(ii) the total energy output of the reactor core in one day (1 day = 8.64×10^4 s). (1 mark)

(iii) the mass of uranium-235 converted in one day. The mass of a uranium-235 nucleus is 3.9×10^{-25} kg. (2 marks)

(d) Discuss the physical properties of nuclear waste that make it dangerous. (2 marks)

22. **AQA Applied Science SC02 Jun 2013** An engineer has been asked to install a hydroelectric generator for a farmer who lives near a hill that is 50 m high. A pipe runs down the hill, as shown below (viewed from the side).



(a) Suggest THREE advantages of installing a hydroelectric generator rather than a diesel-powered generator. (3 marks)

(b) In the hydroelectric system, water from the top pool flows through a large, smooth pipe to the lower pool. Explain why it is important that the pipe should be smooth. (1 mark)

(c) Calculate how much gravitational potential energy (GPE) is converted into other forms of energy when 8 kg of water flows down from the top pool through the generator to the lower pool. State the correct unit in your answer. Assume $g = 10$ m s^{-2}. (3 marks)

(d) The engineer stated that "not all the gravitational potential energy is converted into electrical energy at the generator".

Name TWO forms of energy, other than electrical, that will be produced as the water flows down the hill and through the generator. (2 marks)

(e) (i) Sometimes, the water flows fast enough to convert gravitational potential energy into other forms (including electrical energy) at a rate of 2000 W (2 kW). However, the generator only produces 600 W of electrical power. What is the efficiency of this system? (2 marks)

(ii) Suggest TWO reasons why the generator may NOT produce a constant power of 600 W. (2 marks)

(f) After the generator is set up and working, the farmer finds that the energy from the generator has saved him £43.20 in one month. What is the average power generated during this month? Include the correct unit in your answer. Assume that a month contains 720 hours, and that the farmer pays 15p (£ 0.15) per unit of electricity. (3 marks)

23. HKDSE 2012

(a) It is known that even on a clear day, the atmosphere absorbs an average of 26.8% of solar power. Find the maximum solar power per unit area reaching the Earth's surface. Given: solar constant = 1366 W m^{-2} (1 mark)

(b) State the energy conversion of a solar cell and suggest a way to improve its absorption of energy. (2 marks)

(c) *Solar Impulse* is a Swiss project to make a solar-powered aircraft that can fly long distances. Its first prototype HB-SIA has four engines driven by batteries which are charged by the solar cells installed on the aircraft. HB-SIA made a successful international flight in May 2011. The specifications of HB-SIA are as follows:

- Power of each engine is 7.35 kW
- The surface area of each solar cell panel = 0.0172 m^2
- Conversion efficiency of solar cells = 12% during midday at normal incidence of solar radiation

(i) Assume that all the electrical power output of the solar cells is shared equally by the four engines. Estimate the number of solar cells required if each engine is driven to its full power. Assume that all the solar cells on HB-SIA receive the same solar power per unit area found in (a). (3 marks)

(ii) For the 2011 flight, a total of 11 628 solar cells are installed on HB-SIA for a certain reason, which would not have been enough to drive the four engines to their full power. Suggest a practical reason for such a design. (1 mark)

(d) Explain why solar power is said to be a renewable energy source. Besides solar power, suggest a renewable energy source that is most feasible to be used in Hong Kong. Justify your choice. (3 marks)